2D Position-Sensitive Neutron Detector

DENEX-300TN

User Manual and Technical Specification

Lueneburg, February 2008

1. General

This manual contains important information on understanding the way in which the Denex 300 TN/B detector functions, as well as instructions for installation and operation of the detector. We strongly recommend that you read carefully the instructions contained in this user manual, in order to ensure that your detector functions optimally right from the start.

The detector as supplied is ready for operation. It should be unpacked immediately following delivery, even if the installation and start of operation is planned for a later date.

The transport container should be inspected for any signs of external damage. Transport packaging should be completely removed. The container and packaging material should be stored safely in case of any possible claims for damages.

1.1 Guarantee declaration

The detector you have purchased has been manufactured with great care under continuous quality control. Should however any defects or faults be found over a period of 1 year from the date of purchase, please inform Denex in writing either with information on the fault or a description of the problem at the address below. Assistance will be given without charge.

This guarantee is void in the case of damage caused through accident (e.g. mechanical shock), improper operation (e.g. the use of excessively high anode or drift voltages) and acts of nature beyond control (e.g. lightening, flooding etc.). This guarantee will lapse, if it transpires that in any way unauthorised changes are made to the detector.

In the case that the detector has to be shipped to Denex for repairs, please ensure that the detector is free of contamination and appropriately packed, as Denex cannot assume responsibility for damage that may be incurred during transportation.

Guarantee claims should be addressed to:

DENEX, Detektoren für Neutronen und Röntgenstrahlung GmbH
Stöteroggestrasse 71
D-21339 Lüneburg (Germany)
Tel. +494131 248932
Fax +494131 248933
E-Mail: denex@t-online.de

Following expiry of the guarantee period the detector may also be returned to the above address for repair. In this case repair costs will be invoiced.

CE EU-Declaration of Conformity
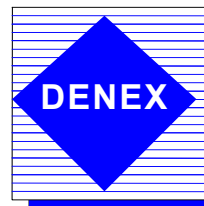
The Manufacturer of the Product covered by this Declaration is

DENEX- Detectors for Neutrons and X-Rays GmbH
Stöteroggestrasse 71
21339 Lüneburg
Federal Republic of Germany

The Directives covered by this Declaration

97/23/EEC Pressure Equipment directive (PED) Section EEC No. L18158.1 from 9.7.1997

Test pressure 6 bar. Calculated according to AD 2000, Bulletins 5D and W7

89/336/EEC Electromagnetic Compatibility directive as amended

The Product covered by this Declaration

2D-position-sensitive detector for the registration of neutrons
Type: **DENEX-300TN Serial No. 0706-0015**

The manufacturer hereby declares under his sole responsibility that the product identified above, by reason of its design and construction, complies with the essential health and safety requirements of the EU-directives.

Attention!
The attention of the specifier, purchaser, installer, or user is drawn to special measures and limitations to use that must be observed when this product is taken into service to maintain compliance with the above directives. If changes are made to the product without prior agreement with the manufacturer, this declaration will become invalid.

Signed: ....

Authority: .....

2. Working principles of Denex detectors

2.1 Primary ionisation

The physical principle employed for the detection of photons or neutrons is based on their interaction with the gas present in the detector chamber. Absorption of the incoming photon or neutron by the gas is accompanied by local ionisation of the gas and the production of electrons and positive ions. A Denex detector is in principle constructed like an electrical plate capacitor (Fig. 1). The plates are designated as electrodes with the anode connected to the + pole and the cathode to the – pole of the voltage supply U. The electrodes are located opposite and parallel to each other and are separated by a small distance d within the gas-filled chamber.

The voltage U applied to the electrodes serves to generate a homogeneous electric field F between them. When photons or neutrons enters the space between the electrodes, collisions with the gas molecules along their trajectories lead to the creation of positive and negative charge carriers (ions and electrons) which are then attracted to the correspondingly oppositely charged electrodes. The resulting charge impulses can be measured as electrical impulses i.
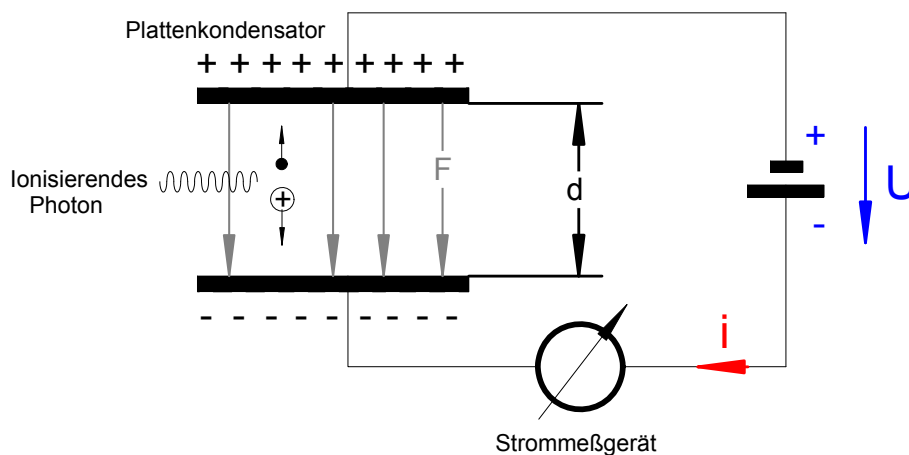

Fig. 1: Measurement of the ionisation current

The applied voltage U and the distance between the electrodes d are chosen such that U is large enough and d is small enough to ensure that the charge carriers are collected quickly enough by the electrodes to avoid their recombination. In the case of low energy photons the entrance window of the detector has to be very thin to allow transmission of the photons without significant energy losses and thus to ensure that they can give up almost their entire energy within the detection volume.

For the efficient detection of photons and neutrons it is therefore necessary to give careful consideration to detector design and to the selection of the window material and the detection gas.

2.2 Secondary ionisation

In contrast to photons, neutrons can only interact with atom nuclei, for example via absorption. The absorption process involves incorporation of the neutron into the atom nucleus. This generally leads to excitation of the atom nucleus and the subsequent emission of particles.
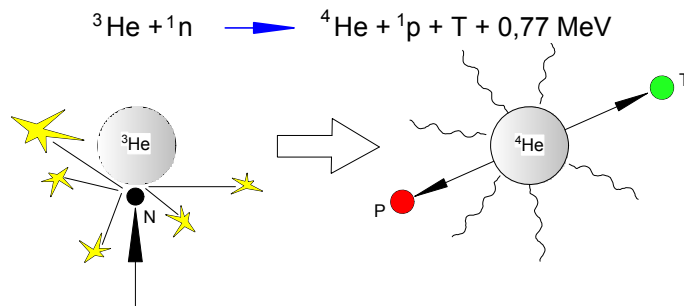
$$^3\text{He} + {^1\text{n}} \longrightarrow {^4\text{He}} + {^1\text{p}} + T + 0{,}77 \text{ MeV}$$

Fig. 2: Nuclear reaction between a neutron and ^{3}He

Fig. 2 shows schematically such a reaction between a neutron and a ^{3}He-atom. Excitation of the ^{3}He-atom by the incoming neutron leads to the emission of a proton and a tritium atom; + 0.77 MeV is released and the ^{3}He-atom is transformed to ^{4}He. The proton (p) and Tritium (T) released generate positive und negative charged particles via collisions with the gas molecules along their trajectories. These are attracted to the correspondingly oppositely charged electrodes of the capacitor plate.

As illustrated in Fig. 3, the two electrodes are normally configured in practise as a cylindrical capacitor or as tube-detector or counting tube.
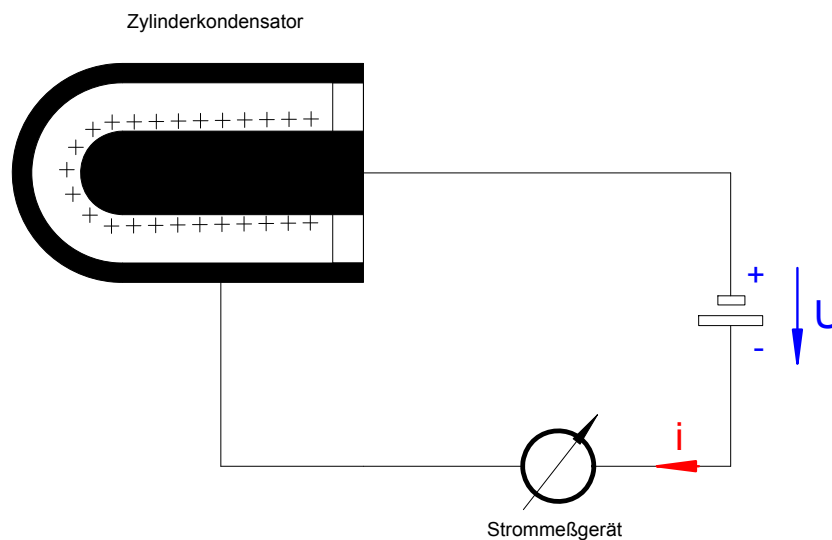
Fig. 3: Detector as cylinder-capacitor

2.3 The proportional counting tube

Whereas in a plate capacitor only the directly or indirectly generated charge carriers contribute to the signal, the proportional detector makes use of an amplification effect that is based on the multiplication of these charge carriers in the gas volume. The positive electrode (anode) of the cylinder-capacitor illustrated in Fig. 4 takes the form of a thin wire, in the neighbourhood of which, free electrons between two collisions with the gas atoms are so strongly accelerated, that they can generate further charge carriers.

A primary electron thus produces an avalanche of secondary electrons (Fig. 5), so that ultimately a much greater number of charge carriers is generated than result from the primary ionisation of a single photon or neutron.
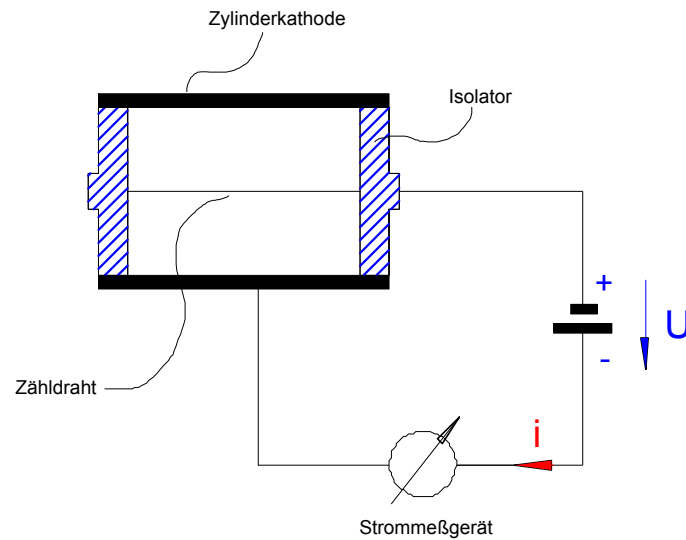
Zylinderkathode

Isolator

+

−

U

i

Zähldraht

Strommeßgerät

Fig. 4: Principle of the proportional counting tube

The amplitudes of the charge impulses at the counting wire are proportional to the primary ionisation via the gas amplification factor which increases with increasing anode voltage U. The upper limit to the anode voltage is dependent on the diameter of the anode wire as well as on the composition and pressure of the detection gas. Raising the anode voltage U beyond the corresponding limiting value results in an electrical discharge and consequently the destruction of the counting tube or detector.

Einfallendes Photon

Elektron

Zähldraht
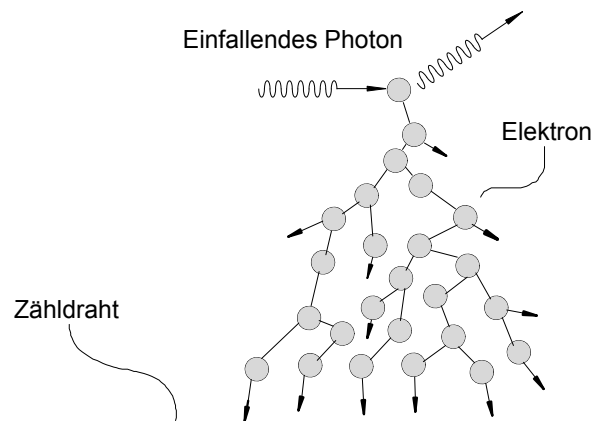
Fig. 5: Principle of gas amplification

The signals measured therefore correspond to the short-lived impulses caused by the highly mobile electrons generated by gas amplification. Proportional detectors are therefore mainly used to count these impulses, although the proportionality between impulse height and primary ionisation allows the nature and energy of the radiation to be differentiated.

Since very small dead times are an essential feature of proportional counters (Fig. 6), the maximum count rate depends solely on the time interval needed by the counter following registration of an

impulse to be ready to register a further impulse. This so-called resolution time amounts to less than 1 µs in good quality detectors, so that count rates in excess of 10^6 counts /s are achievable.
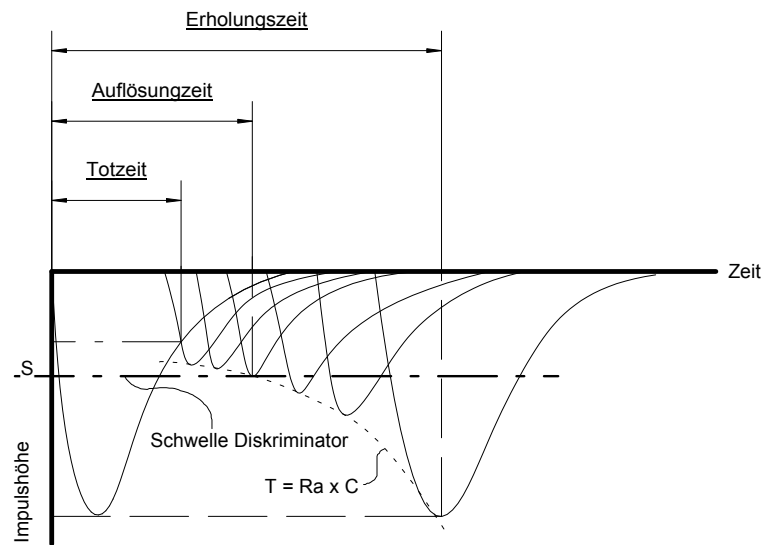

*Fig. 6: Impulse voltage as a function of time (**S** Discriminator threshold)*

2.4 Detection gases

Noble gases such as helium, argon or xenon are employed as detection gases, whereby special measures have to be taken with regard to the termination of the discharge process. This requires the use of stopping or quenching gases, in particular hydrocarbons, such as methane, butane, ethane, carbon dioxide or tetrafluormethane.

The operating lifetime of closed detectors filled with noble gases is practically unlimited. However, leakage and ageing processes can lead to changes in the detector characteristics. Decomposition of the hydrocabon gases as a result of the ionisation events contributes to such ageing processes. These hydrocarbon gases are thus preferably employed in open detectors in which the detection gas flows dynamically through the detection chamber.

Depending on the specific application there are various types of proportional detector. Detectors for low energy photons, for example, are fitted with thin-walled entrance windows. On the other hand, detectors for the measurement of high energy photons have to be filled with gases of sufficiently high absorption capacity to achieve satisfactory detection efficiency. In detectors for neutrons, special gas mixtures are employed in which especially strongly ionising secondary particles are generated. The large charge impulses that result can easily be distinguished from the relatively small impulses generated by photons. This special feature of proportional counters therefore makes them especially suitable for the separate measurement of neutrons in the presence of photons.

2.5 The characteristic curve

Following the arrival of an impulse in a proportional detector, no further impulse can be detected during the so-called dead-time (see Fig. 6). After the dead-time has expired, impulses first reattain their original magnitude, when the so-called recovery-time has expired ($T = R \times C$, where R = anode-

resistance (Ra) and C = detector capacity). For registration in a counting device the resolution time is decisive. The time period after resolution of an impulse is determined by the discriminator threshold (S) (resolution time).

The amplitude of the impulses depends only on the detection gas, the thickness of the anode wire and the applied voltage U, although the amplitude of the impulses generally increases with increasing anode voltage U.

The appropriate operating voltage for the detector is established by determining the so-called characteristic curve, which illustrates the dependence of the count rate on the applied voltage U.
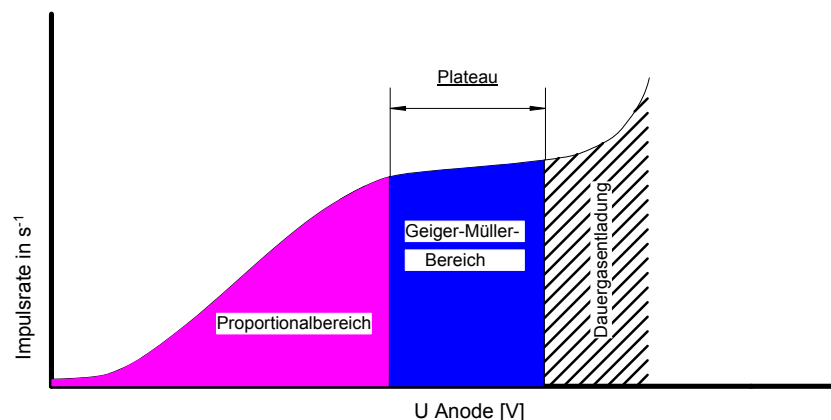

Fig. 7: Characteristic curve for a detector

 Fig. 7 shows a schematic of such a curve, determined e.g. with a discriminator threshold of 0 V. A distinctive feature of the characteristic curve is the so-called plateau or "Geiger-Müller-Regime", which for good quality detectors should extend over a voltage range of more than 100V and a have slope of a few %. The operating voltage of the detector is selected such that random voltage fluctuations do not lead to departures from the voltage range of this plateau regime. Electron avalanches created outside this voltage regime will propagate along the entire length of the counting wire. The resulting charge impulses are much larger than those generated in the proportional regime and their magnitudes are independent of the nature and energy of the photons or neutrons entering the detector.
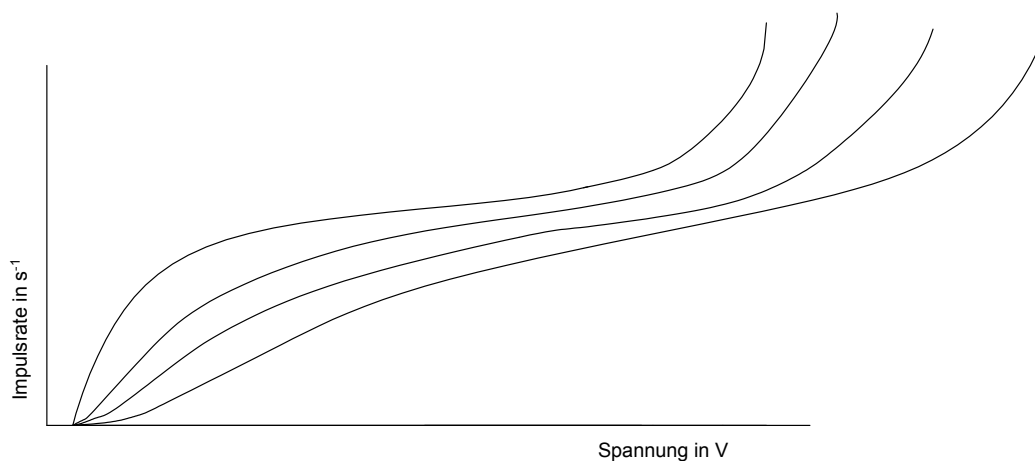
Fig. 8: *Characteristic detector curves for various discriminator thresholds*

The discrimination required for the separate measurement of neutrons in the presence of photons is here more difficult or even impossible to achieve. In this case, the anode voltage should not be raised above the average plateau value. Above and beyond the average plateau value the count rate starts to increase more rapidly as a result of interference effects, until finally a continuous gas discharge takes place that leads to destruction of the detector.

Fig. 9 shows a circuit diagram of a proportional counting tube with its associated electronics.
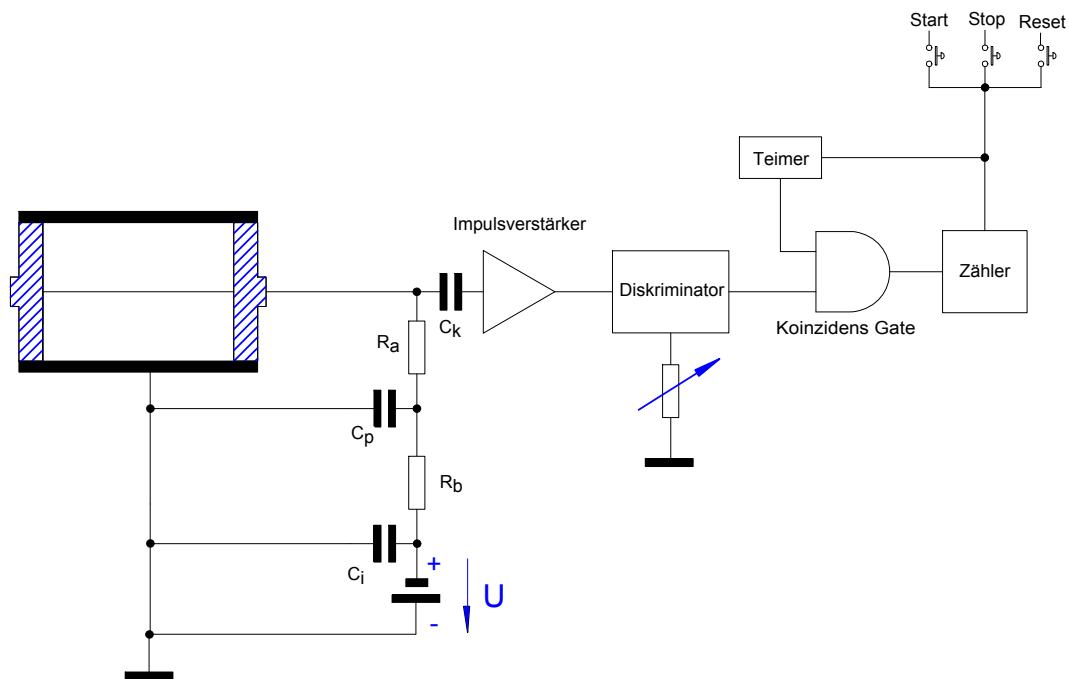

Fig. 9: *Circuit diagram of a proportional counting tube with electronics*
C_k Coupling capacitor, C_p Pump capacitor, C_i Integrator capacitor
R_a Work resistor, R_b Current limiting resistor

2.6 The position-sensitive proportional counter

The position-sensitive proportional counter is designed to ascertain the specific position in a radiation field from which the incoming photon or neutron originates.

As shown in Fig. 10, a 1-D position-sensitive detector for the detection of scattered photon or neutrons can be constructed by arranging counting tubes next to each other in arrays. The positional resolution of such devices corresponds to the diameter of the counting tubes employed. Between the individual counting tubes there is a dead zone which is created by the walls of the counting tubes. Such arrangements are very expensive and difficult to operate since each counting tube needs its own electronics and these have to be exactly trimmed to match each other and should show the same temperature drift.
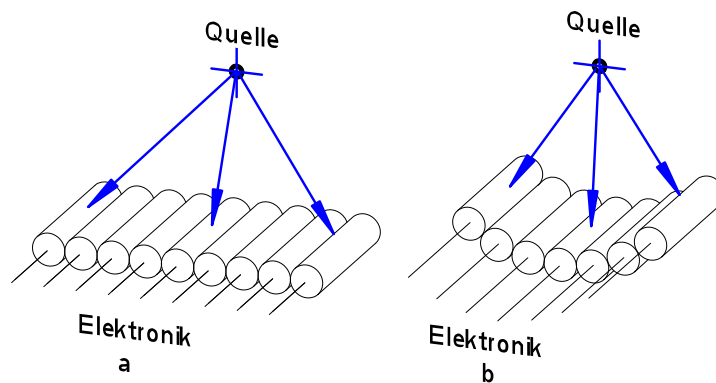
Fig. 10: Arrangements of proportional counting tubes as position-sensitive detectors
***a)** Linear arrangement, **b)** Circular arrangement*

The DENEX solution to this problem is to combine each individual counting tube into the proportional counter.The cathodes are connected via a delay line.
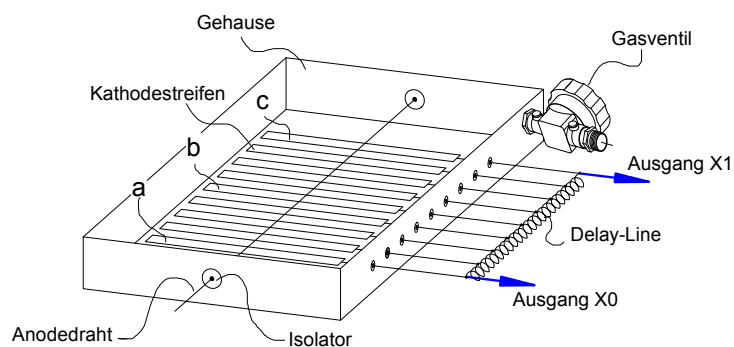

Fig. 11: Design principle of the DENEX-1D-Detector

Fig. 11 shows the arrangement used. A single anode wire is located perpendicular to the array of cathodes. The signals are registered in the individual cathodes and are transmitted via the delay line through the signal outputs X0 and X1 to the corresponding electronics. The spatial resolution is simply given here by the distance between one cathode and the next one. In a 2D-detector an additional array of cathodes perpendicular to the first array is employed.

2.7 The delay line readout method

The advantages of the delay line readout method, compared to other readout systems, are as follows:

a)   parallel signal read out (wire per wire)
b)   large frequency range
c)   simple electronics for signal handling
d)   signal amplitude independence

A delay line consisting of "L" und "C" elements with a total delay time depending on detector type from ca. 100 ns to 400 ns and an impedance of 50 Ω is employed. The first electronic element connected to

the output of the delay line is a linear, low-noise impulse pre-amplifier with 56 dB amplification. For correct timing-signal information (independent of the signal amplitude) this is followed by a CFD (Constant Fraction Discriminator).

2.8 Time measurement for position decoding

Two principal methods for registering small time differences are available:

1) The signals X0 and X1 are transmitted via a "Gate and Delay Generator" for position-specific detection. One signal output of the delay line provides the start signal and the other the stop signal. The measured time difference is transformed into a voltage by means of a TAC (Time Analogue Converter) and transmitted via an ADC (Analogue Digital Converter) to an MCA (Multi-Channel Analyser). Alternatively, as shown in Fig.12, the start/stop-signals can be transformed into digital addresses using a TDC (Time Digital Converter) and transmitted directly to the MCA.

2) The anode signal provides the start signal and the cathode signal the stop signal. The time difference is measured and registered as described in a) and Fig. 12 (see Fig. 13).
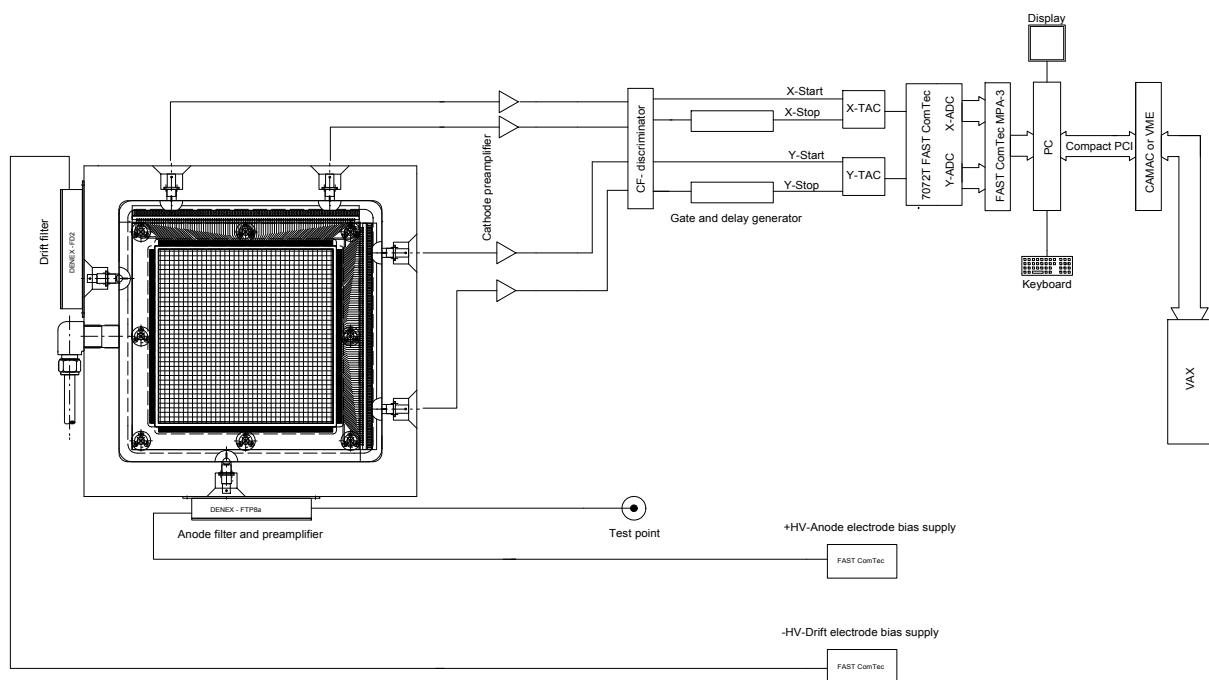
Fig.12: Circuit diagram for position decoding using only the cathode signals

The cathode method requires two additional delay units in order to obtain a well-defined stop signal. Setting the stop signal with the delay units allows the spectrum to be shifted on the display. These delay units are not necessary in the anode method. However, other special requirements must be fulfilled. The use of coaxial cables means that consideration must be given to the phase and temperature stabilities as well as mechanical loading, in order to ensure that constant, reproducible start signals are obtained.

Fig.13: Circuit diagram for position decoding using both the anode and cathode signals

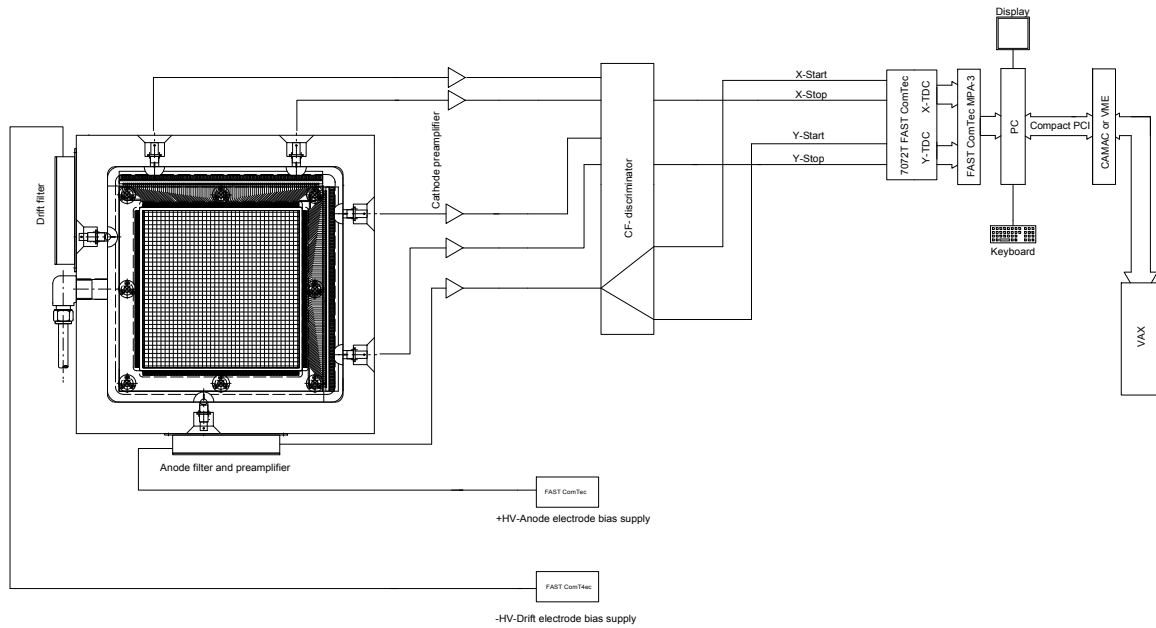## 3. Design and construction of the DENEX-300TN detector

The DENEX-300TN detector is a 2-dimensional position-sensitive multi-wire proportional counter for the detection of thermal neutrons.

The principle of position decoding is illustrated in Fig. 14. The externally applied voltages generate strong and almost homogeneous electric fields (red arrows) between the electrode planes. When a neutron undergoes absorption in this detection volume, the free electrons released via the ionisation process are accelerated towards the anode (blue arrow). The strong electric fields in the neighbourhood of the anode wires accelerate the electrons such that charge multiplication occurs by an avalanche process.

The resulting charge avalanche is registered as an electrical impulse (green arrow) by both read-out cathodes (X and Y cathodes) and fed into the delay line, which divides the incoming impulse into two equally strong pulses. These flow to the two ends of the delay line.

The delay lines consist of a series of LC-Elements that result in a delay of 2.7 ns between the pulses from two adjacent cathode wires. The longer the distance of the event from the end of the delay line, the greater is the time needed before it is registered at this end of the delay line. The X and Y coordinates of the position of the event can thus be determined from the arrival times of the two impulses.
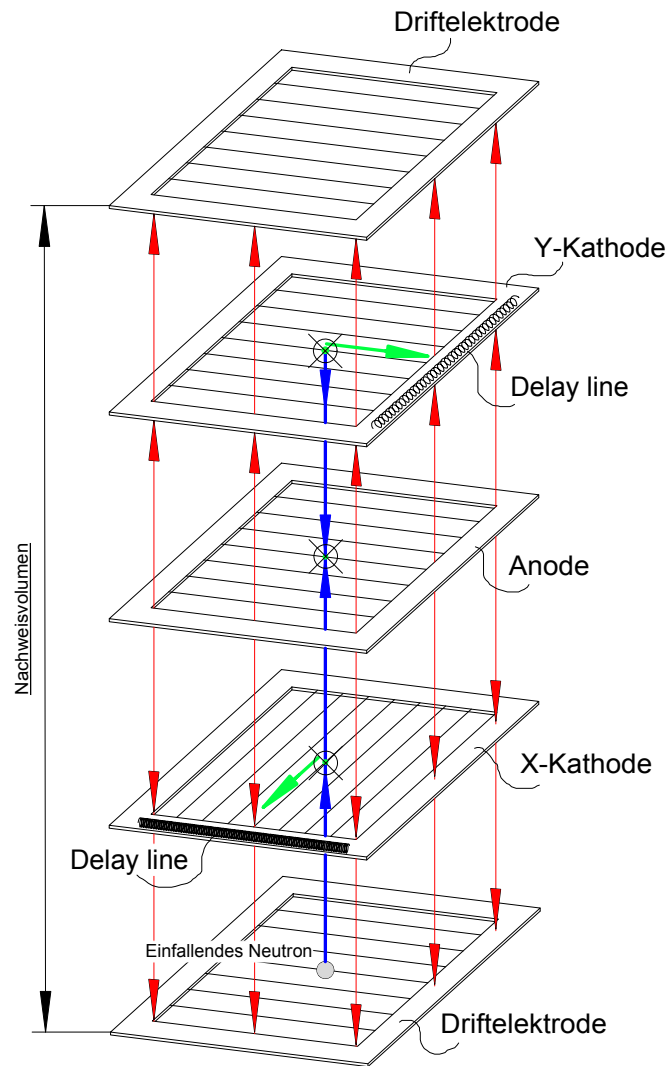
Fig. 14: Principle of position decoding in a 2D-multi-wire proportional detector with a delay line

3.1 Mechanical construction of the DENEX-300TN detector

The DENEX-300TN detector consists of a housing unit (Al-Mg3) that supports a series of electrodes and which is closed by a pressure-resistant cover plate (Al-Mg4.7M) (Fig.15).The neutron entrance window is integrated into the cover plate. The size of the window, 300 mm x 300 mm, corresponds to the area spanned by the electrode wires. The detection volume is limited by two drift electrodes each located at a distance of 5 mm from the X and Y cathodes. The distance between the first and second drift electrodes corresponds to 20 mm. The first drift electrode consists of a metallic foil which has been vulcanised with insulating material directly onto the window in order to avoid having a dead volume between the drift electrode and the entrance window. All materials are chosen such that neutron absorption or scattering effects can practically be neglected.
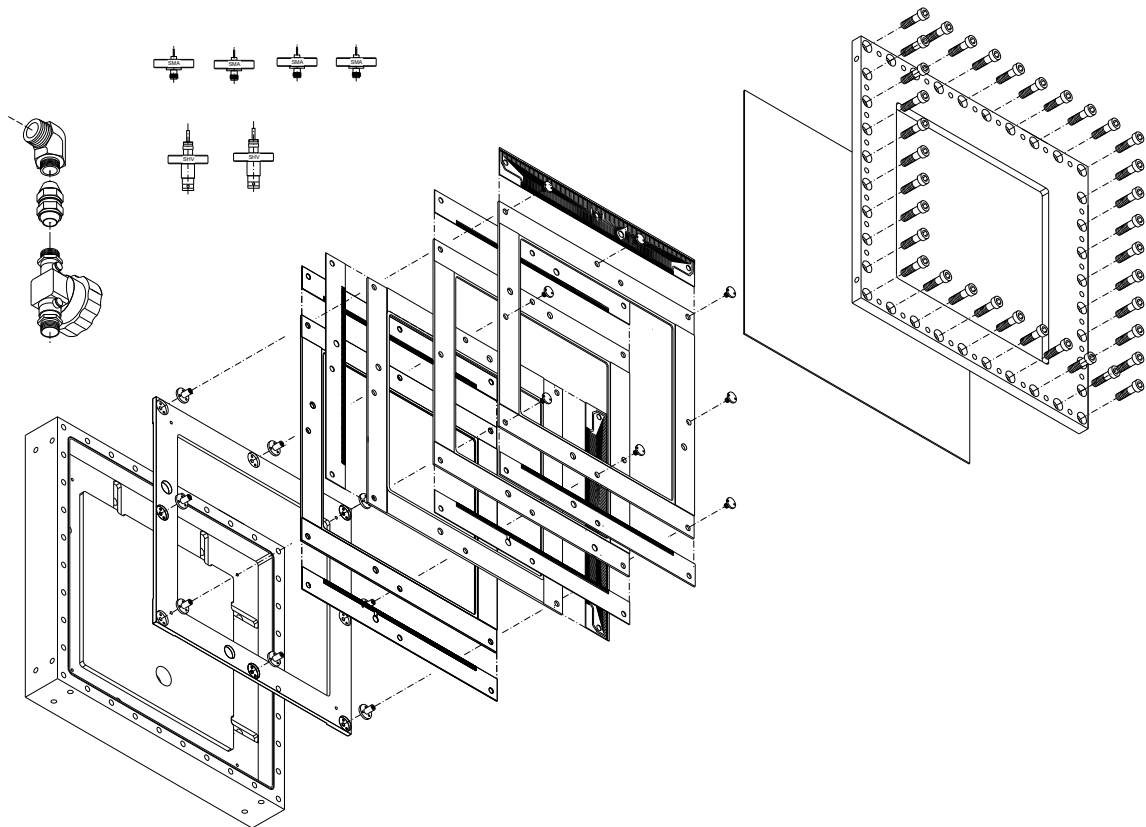
Fig. 15: Diagram showing the housing, the electrodes and cover plate of the DENEX-300TN detector

3.2 Quality control during production

During the production process DENEX tests the detector with ^{55}Fe und ^{57}Co-photons, in order to check the quality of the individual components and the performance of the entire detector system.

Tests with ^{55}Fe involve the measurement of photons with low energy (5.9 keV) employing flowing Ar-CO_2 as counting gas. The experimental setup is shown in Fig. 16.

Fig. 16:   Testing the DENEX-300TN detector with a ^{55}Fe-source

Initially experiments are carried out to test the homogeneity of the signal over the entire area of the detector. Effects due to defective wires or entrapped dust particles 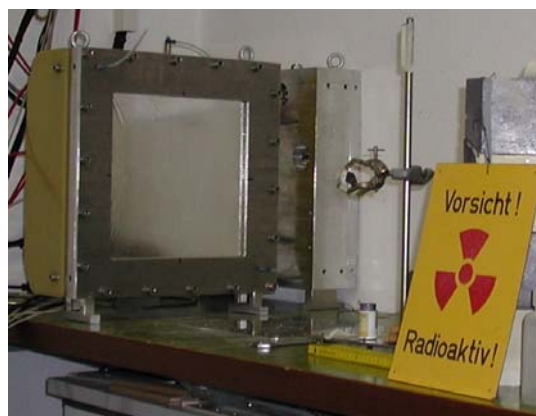are easily identified and can be rectified immediately by replacement or removal. The next experiment involves determination of the anode characteristic curve (Fig. 17) which allows the quality of the detector to be assessed. In this case the count rate vs applied voltage curve is characterised by an excellent plateau regime between Ua 2670 V and Ua 2740 V.

Kennlinie DENEX-300TN (55Fe und Ar-Co2)
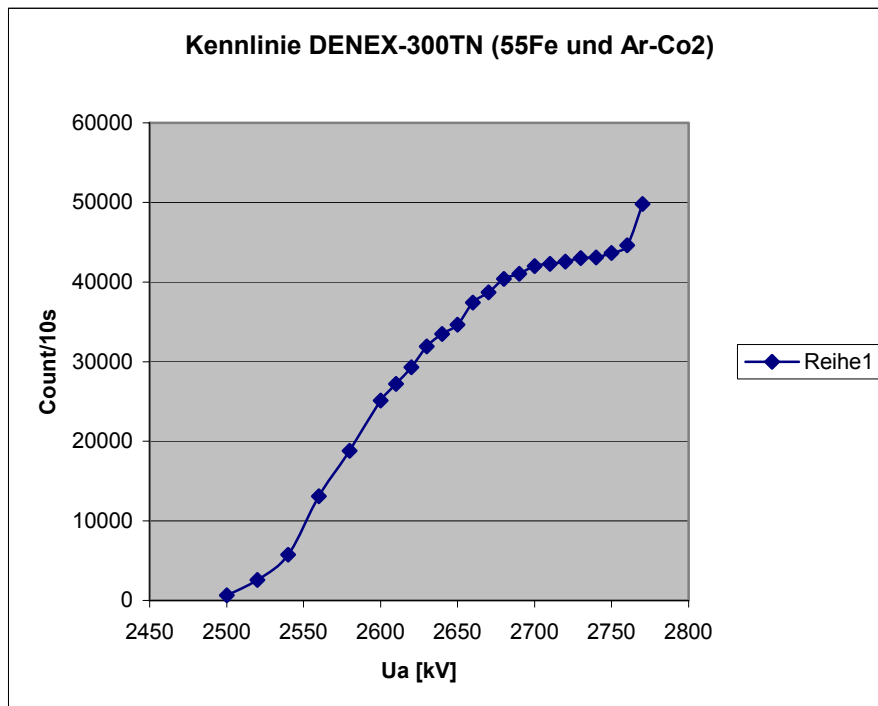
Fig.17: Anode characteristic curve of the DENEX-300TN/B detector determined with a ^{55}Fe-source

Further tests are performed with the ^{55}Fe-source in order to check the positional resolution of the detector. The image of the pliers so obtained (Fig. 18) allows specific details, such as for example, the spring between the handles or the suspending cord with diameters of ca. 0.6 mm to be resolved. Although this test object is very simple, it enables the spatial resolution of the detector to be tested effectively.

The image in Fig. 18 contains in total 1024 x 1024 channels. Line scans across the image in the X and Y directions are shown in Fig. 19. Each channel corresponds to a distance of ca. 0.3 mm.
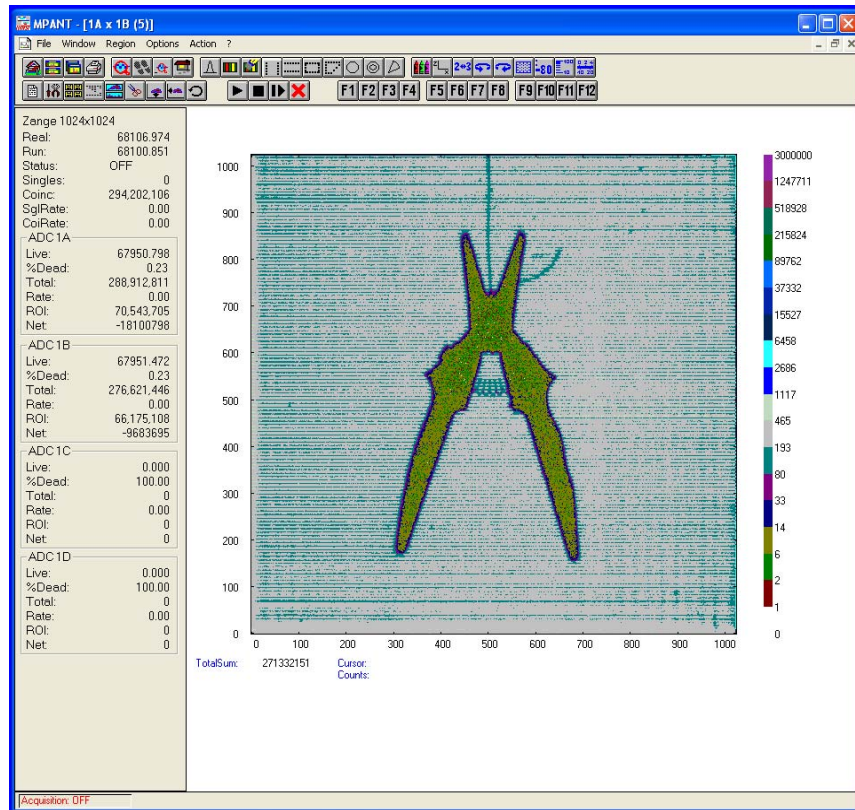
Fig.18: Test of the positional resolution with a ^{55}Fe-source
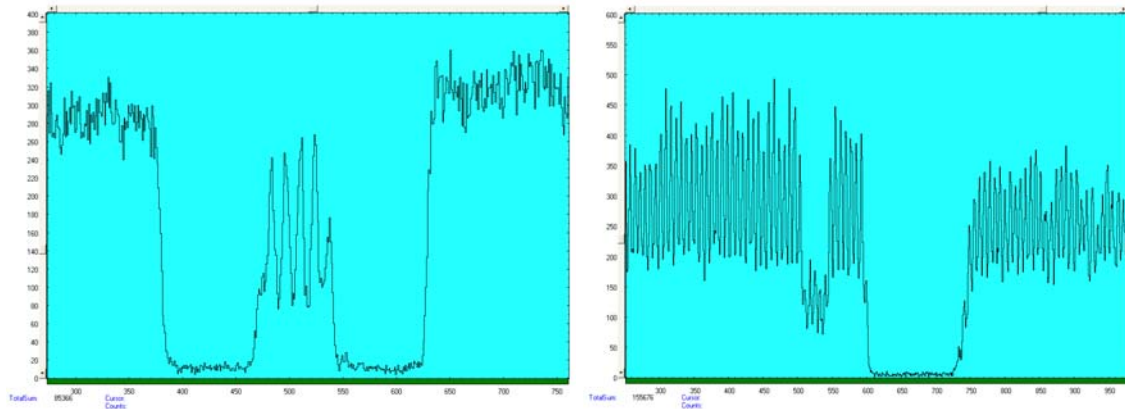
Fig. 19: Line scans in the X and Y directions of the spring and the cord

After testing with ^{55}Fe, the detector is closed with a pressure-resistant covering plate and subjected to pressure and leakage tests (5 bar overpressure with 10^{-9} mm bar/l s). The detector is then filled with an Ar-CO$_2$ gas mixture at 1 bar and again tested for contamination using a ^{57}Co-source. The detector is then heated and evacuated over a period of 5-6 days to remove hydrogen. Subsequently, the detector is tested once more with respect to gas tightness and functionality. When all these tests are successfully completed, the detector is filled with the gas mixture (^{3}He-CF$_4$) required by the customer and the detector as shown in Fig. 20 is now ready for shipping.
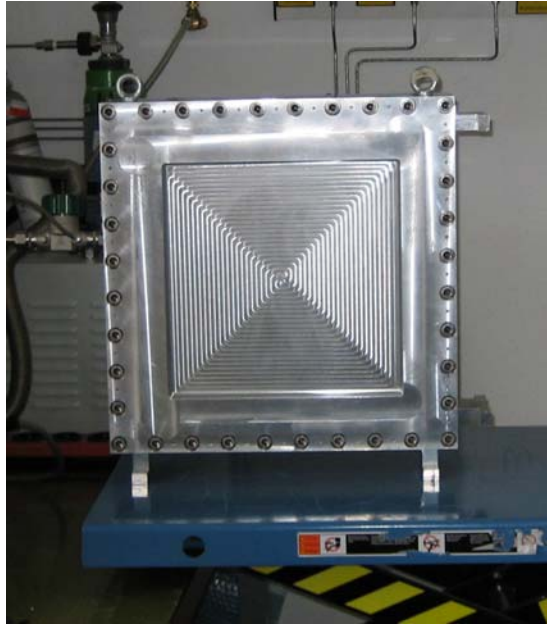
Fig. 20: The finished DENEX-300TN/B detector

4. Installation and initial operation of the detector

4.1   General precautionary measures for the handling and operation of the detector:

The DENEX-300TN detector is an extremely sensitive measuring instrument that should be treated with extreme care. When the detector is put into operation or is running, this means that voltage is being applied to the anode or the drift electrodes and it should be ensured that:

- the detector is not subjected to any mechanical forces such as jolts or vibrations; however it may be mounted and operated on a goniometer stage.

- no sudden voltage changes are caused by removal of the SHV connectors from the anode or drift filter. This could lead to damage of the anode and all the pre-amplifiers. It is recommended that the high voltage always be switched off via the high voltage supply unit which as a result of its very large time constant can avoid any unacceptably rapid voltage changes.

4.2   Detector orientation

Normally, the detector is delivered with the geometry as illustrated in Fig. 21. The resolution along the X-axis is better than along the Y-axis because the anode wires are oriented horizontally, i.e. parallel to the X-axis. The detector may be rotated by 90° to interchange the X and Y axes, if e.g. a better resolution is desired in the vertical direction.
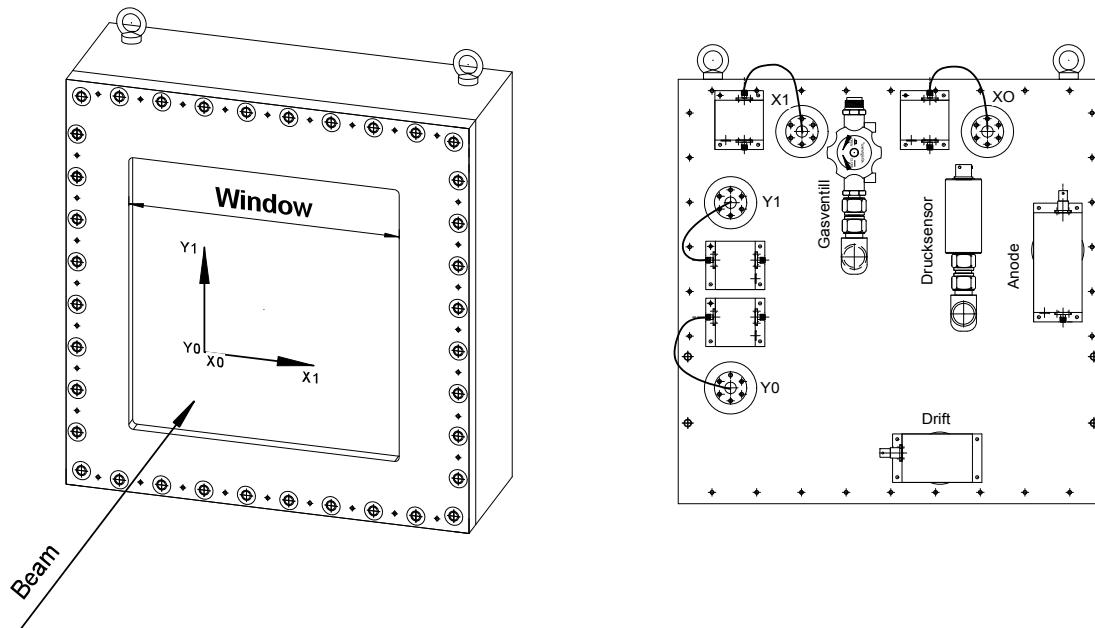
Fig. 21: Front and rear views of the DENEX-300TN detector

4.3   Connecting the electronics to the detector

- First connect the anode and drift high voltages to the NIM-high voltage supply using the two red cables supplied. Take care that the anode is connected to the positive and the drift to the negative voltage respectively.

- Connect the cathode preamplifier FTP-110 and the anode preamplifier FTP-111 with the NIM-module N-145 using the LEMO-cables supplied, see Fig. 22. Adjust the individual trimming potentiometers with a small screwdriver until the voltage of the corresponding channels reaches a value of approx. + 9.7 V.
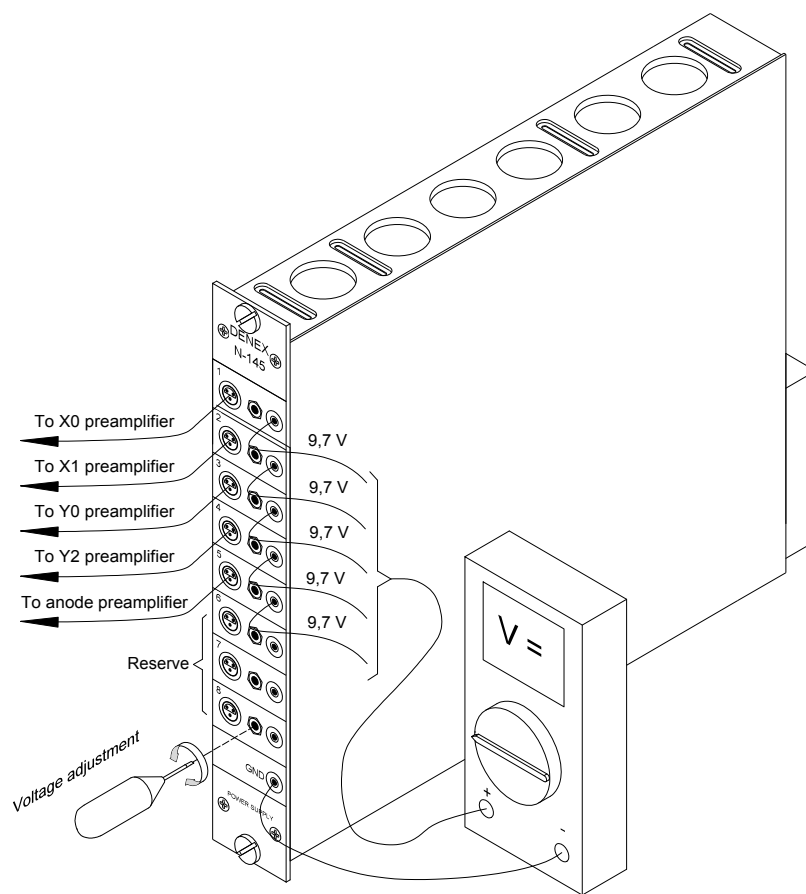
Fig. 22:   Connecting the detector preamplifier to the NIM-module DENEX-N-145

- Connect the preamplifier to the NIM-main amplifier TFA-111 using the SMA-coaxial cable supplied as shown in Fig. 23.

- Connect the A-outputs of the main amplifier TFA-111 to the inputs of the Ortec discriminator using short LEMO-coaxial cables of **equal length** as shown in Fig. 23. Set the zero-crossing voltage of the individual channels with a small screwdriver, see Fig. 23.
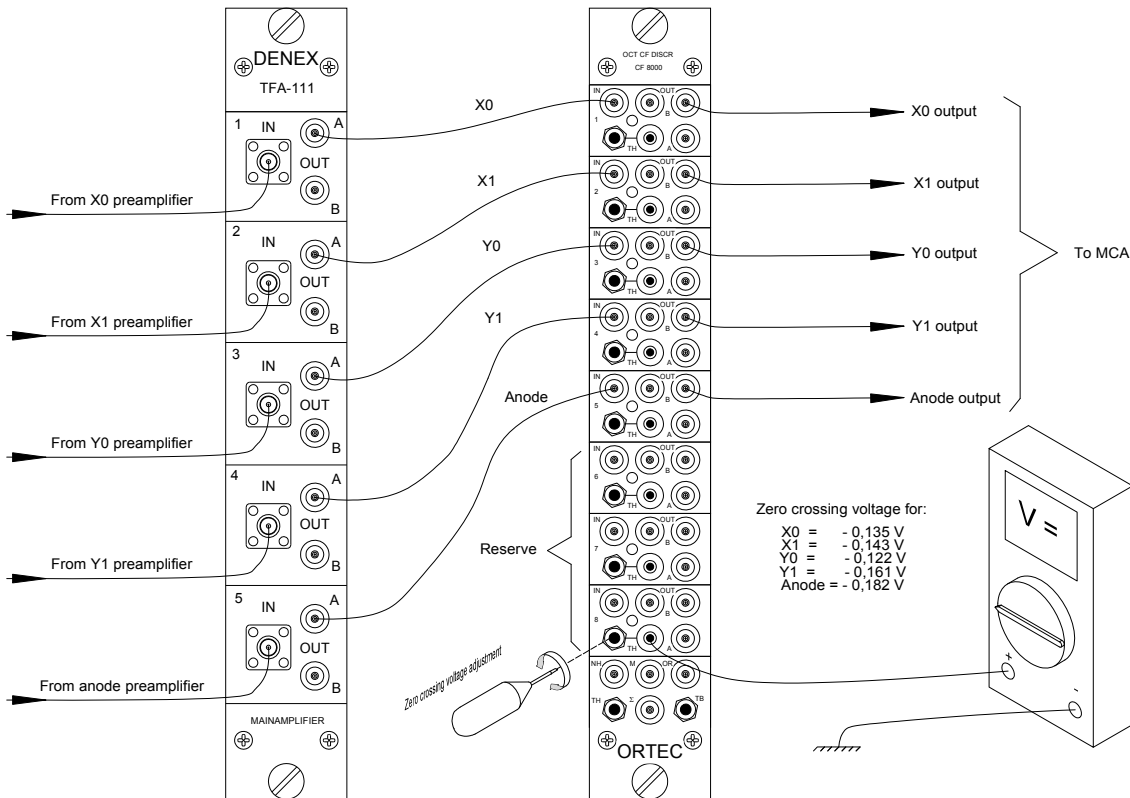
Fig. 23: Connecting the preamplifier to the CFD-8000

4.4   Recording the characteristic anode curve:

Equipment required: An oscilloscope and a pre-selection impulse counter

a) Connect a good oscilloscope, e.g. TEKTRONIX TDS 3054B to the B-outputs of the anode channel main amplifier TFA-111

b) Turn the zero-crossing of the anode-CF-discriminators to a minimum (ca. 7 mV)

c) Leave the drift-high voltage supply unit switched off

d) Open up the neutron beam

e) Now switch on the anode-high voltage supply unit and slowly increase the anode voltage from **zero** volts until the neutron signals just appear on the oscilloscope

f) Connect a B-output of the ORTEC-CFD of the anode channel to the input of the pre-selection impulse counter with a LEMO-coaxial cable. Set the preselection counter such that the anode pulses can be counted for a time of ca. 20 s

g) Start the measurement and note the measured count rate. After each measurement, raise the high voltage in steps of e.g. 50 V until the anode count rate increases dramatically

20

The measured values in the table are used to plot the characteristic anode curve illustrated in Fig. 24.

U-Anode	Count/10s
1800	12
1850	14
1900	41
1950	311
2000	1536
2050	5084
2100	10347
2150	14460
2200	18709
2250	21954
2300	23405

U-Anode	Count/10s
2350	24674
2400	25712
2450	26178
2500	26413
2550	26938
2600	26956
2650	27019
2700	27433
2750	27984
2800	28600
2850	28878

U-Anode	Count/10s
2900	29804
2950	30428
3000	31810
3050	32745
3100	34370

Fig. 24: Characteristic anode curve of the DENEX-300TN detector
at a discriminator setting of -0.7 V.

4.5   Recording the characteristic drift curve of the detector

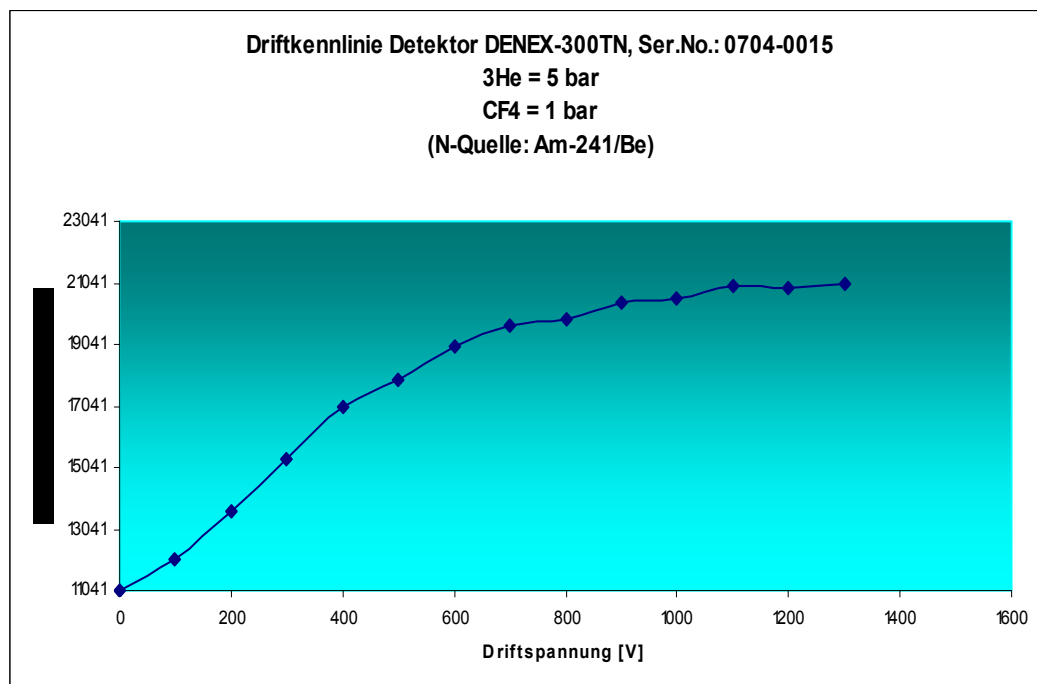Equipment required: Pre-selection counter

a)   Set the anode high voltage to an arbitrary value on the plateau of the characteristic curve (for example 2600 V)

b)   Switch on the drift high voltage supply and set it to 0 V

c)   Set the preselection counter such that the anode pulses can be counted for a time of 20 s

d) Start the measurement and note the count rate. After each measurement raise the drift high voltage in steps until the anode count rate no longer increases.

The measured values in the table are used to plot the characteristic drift curve illustrated in Fig. 25.

U-Drift	Count/10s		U-Drift	Count/10s
0	11041		700	19649
100	12065		800	19873
200	13614		900	20365
300	15330		1000	20547
400	17020		1100	20939
500	17887		1200	20843
600	18975		1300	20974

Fig. 25: Characteristic drift curve of the DENEX-300TN detector

The operating regime of the detector is determined from the course of the characteristic anode and drift curves. We recommend that the anode voltage be set to a value in the range 2400 V to 2900 V. Note that the drift voltage should not exceed the limit of -1000 V and that it should be held constant for each anode voltage.

4.6 Adjusting the efficiency

Equipment required: A black ^{3}He-counter with impulse counter

A ^{3}He-counter tube is placed in front of the detector (Fig. 26). Make sure that this counter is black (light-tight). Ensure that the counter captures the entire neutron beam and then measure the maximum count rate. Then, with the same neutron beam, measure the maximum count rate with the Denex detector using an arbitrary anode voltage in the range + 2400 V to + 2900 V, e.g. + 2700 V. Differences in the count rates can be compensated by adjusting the anode high voltage. In this particular example, the DENEX-detector has an operating anode voltage of exactly + 2800 V.
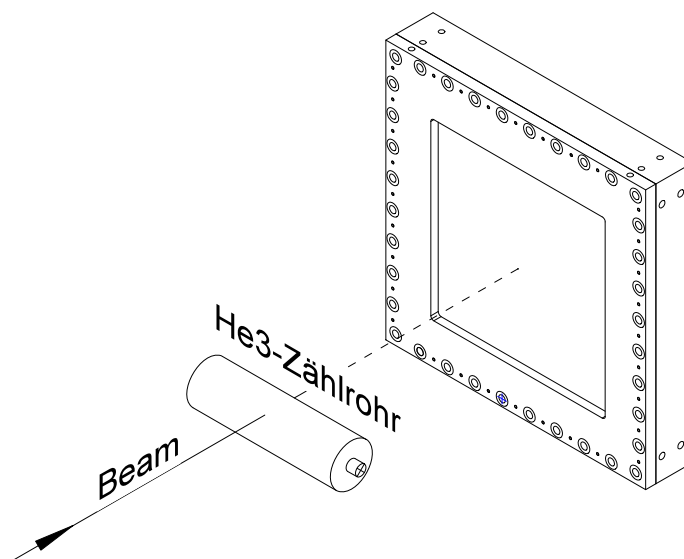

Fig. 26:   Setup for measuring the efficiency

4.7 The Constant Fraction Discriminator (CFD)

General:

A constant fraction discriminator (CFD) is an electronic signal processing device, designed to mimic the mathematical operation of finding a maximum of a pulse by finding the zero of its slope. Some signals do not have a sharp maximum, but short rise times t_r. (see Fig. 27)

The input signals to the CFD are pulses from the cathode and anode of the DENEX detector. However the detector pulses have identical rise times that are significantly longer than the desired temporal resolution in the nanosecond regime. This forbids simple threshold triggering with a TDC (Time Digital Converter) which introduces a dependence of pulse height on trigger time, the so called Time Walk-Effect (Fig. 27 left). Identical rise times and pulse shapes permit triggering not on a fixed threshold but on a constant fraction of the total pulse height (Fig. 27 right) yielding trigger times (Zero-Crossing) independent of pulse height.
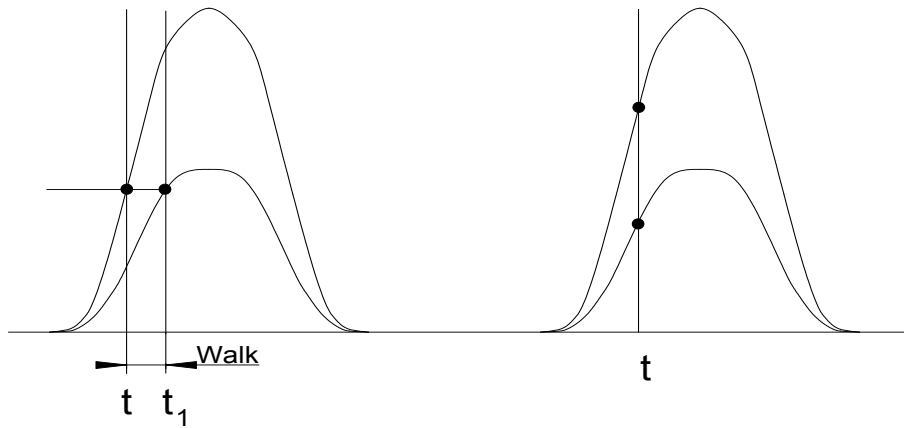
Fig. 27:   Comparison of threshold triggering (left) and constant fraction triggering (right)

Principle of operation:

The incoming signal is split into two components. One of the components is delayed by a time τ where $0 \ll \tau \leq t$ and is inverted, while the other component is multiplied by a factor **c** where **0 < c < 1**. The two components are added together again and the first zero-crossing with a positive first derivative is taken as the trigger time (Fig. 28).

Fig. 28: Function diagram of a CFD

Programming the delay τ on the CFD

Each channel in the CFD-8000 from Ortec has an integrated delay unit which can be programmed in a stepwise manner between 2 ns and 12 ns by plugging in a jumper. In order to programme the correct delay, the following procedure is recommended (method devised by Dr. Thomas Wilpert, HMI-Berlin):

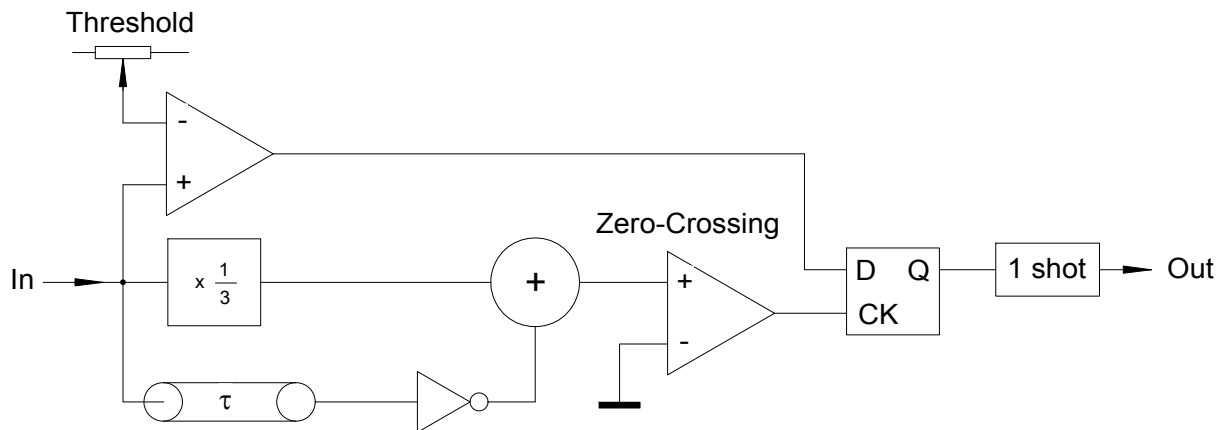Connect the A and B outputs of any of the channels e.g. the X-channel of the main amplifier TFA-111 to the CFD using **LEMO-coaxial cables of equal length** as shown schematically in Fig. 29. Set the jumper of the delay unit for both CFD channels to identical positions.

Note that the LEMO-coaxial cable of the CFD output that provides the stop-signal has to be at least 5 cm longer than the cable providing the start-signal.

Open up the neutron beam to the detector. By toggling the jumper between the two channels of the CFD, measure the optimum delay τ that generates the narrowest peak-width (Fig. 30).

Repeat this procedure for all the remaining channels: X1, Y0, Y1 and the anode.
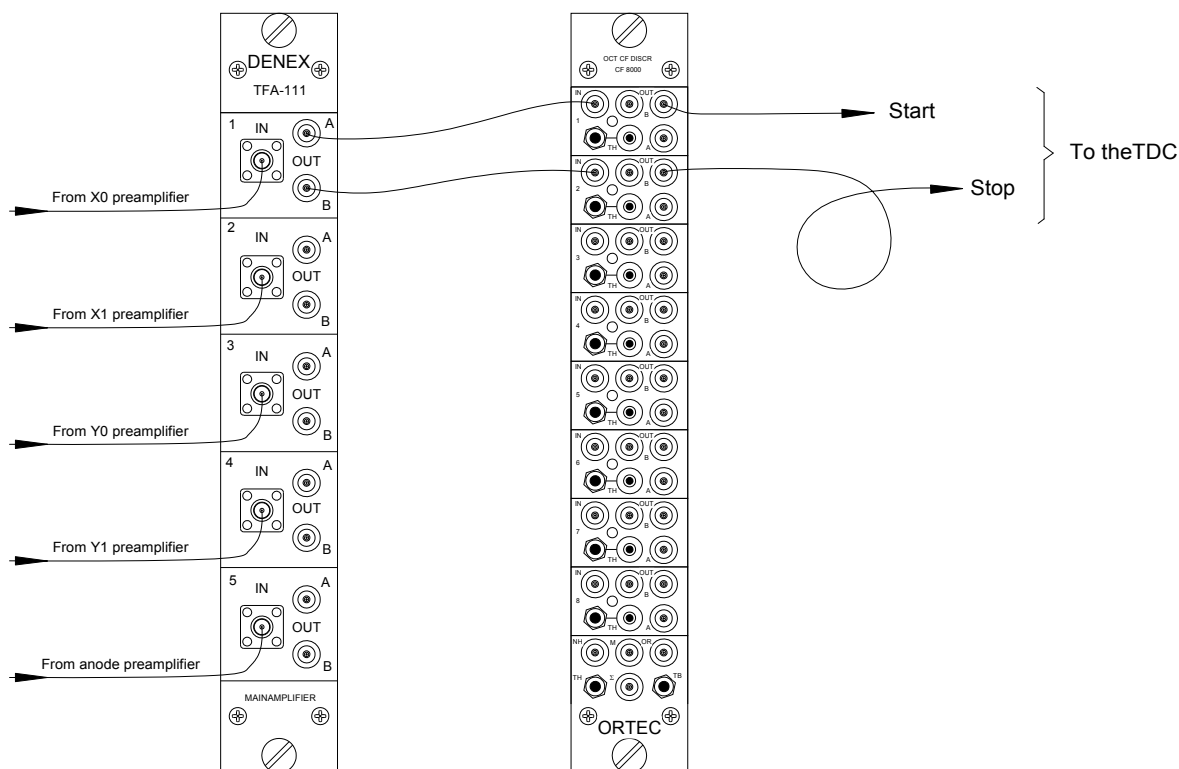
Fig. 29: Adjustment of the internal CFD delay

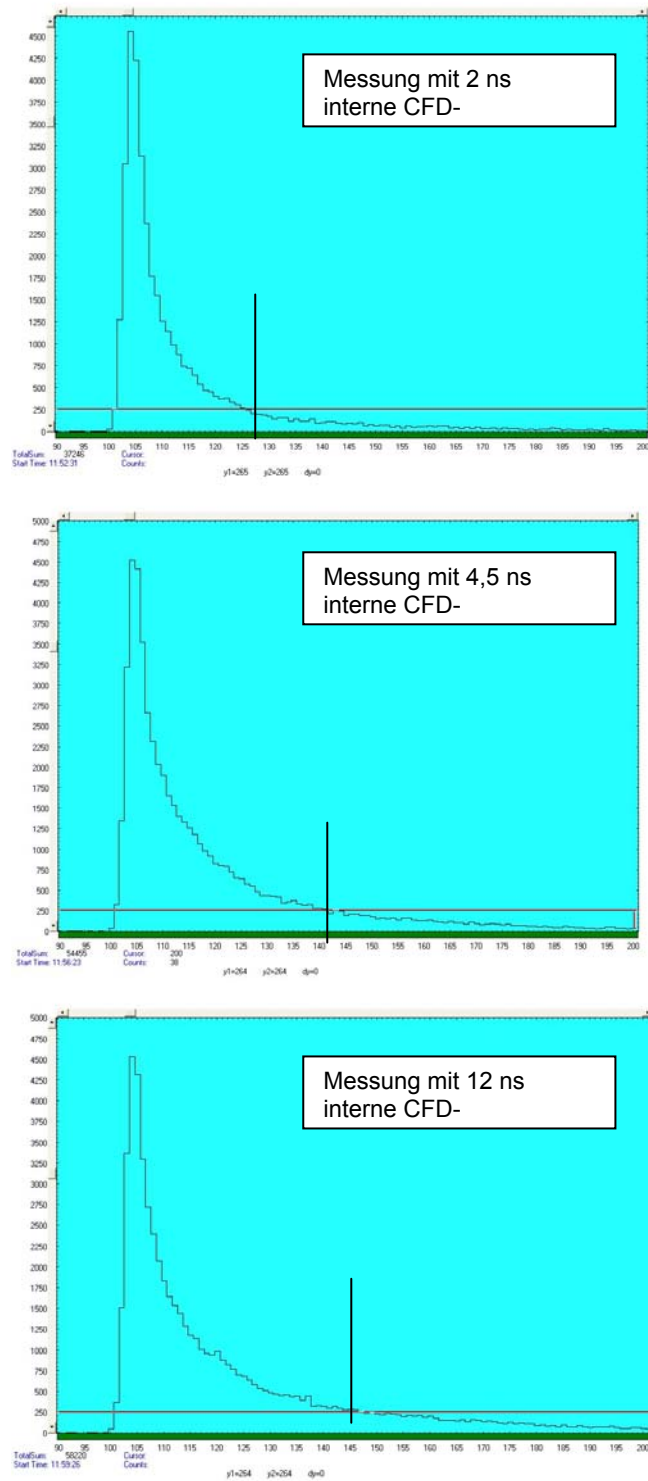*Fig. 30: Programming the delay τ in the CFD*

4.8 Gamma (γ) suppression

An essential requirement for optimum background reduction is the effective shielding of the detector with polyethylene and boron carbide plates to prevent interference by stray neutrons from the reactor or from neighbouring experiments. Successful elimination of these sources of interference will not

however result in zero background because of the contribution caused by ionisation of the unavoidable impurities in the counting gas of the detector, as occurs e.g. in fluorescent lighting. This process is halted by the presence of the additional constituent of the gas mixture, the CF_4 (quenching gas) but does generate undesirable signals whose count rates and amplitudes depend on the magnitude of the anode high voltage (interference effects, see section 2.5). The quenching gas (CF_4) also serves the purpose of limiting the path of the protons and tritium produced by the interaction of the neutrons with the counting gas (secondary ionisation, see section 2.2) and thus enables the desired positional resolution to be achieved.

Interactions between the photons (γ) generated in the detector shielding and the quenching gas CF_4 produce a further contribution to the background. This can be mitigated by reducing the amount of the CF_4 gas in the detector, but this is not always an acceptable option. An alternative is to adjust the zero-crossing potentiometer on the CFD (Constant Fraction Discriminator) until the output of the discriminator shows a γ count rate of zero. The best approach here is to connect an oscilloscope to the main amplifier of the detector and measure the output signal amplitudes in volts. The corresponding zero-crossing potentiometers on the CFD can then be set with the help of a voltmeter.

4.9   Switching off the detector

The detector is switched off by reducing the anode and drift voltages to **ZERO Volt**. The order in which the voltages are reduced is unimportant.

4.10   Detector maintenance

The detector is a closed system filled with noble gas with a lifetime which is practically unlimited. Service and maintenance is therefore generally not required. However leakage and ageing processes ca lead to changes in the detector characteristics.

The detector has been tested for gas tightness at DENEX. If the gas valve remains well closed, the gas pressure should not change significantly over a period up to a decade. Should leakage occur, contrary to expectations, this could lead to damage of the anode. In such a case, the special measures described in the following should be taken:

   a.   Check that the electrical connections are consistent with the diagrams in Figs. 11 and 13. It is especially important to ensure that the anode and drift electrode are supplied with a positive and a negative voltage respectively.

   b.   Carry out the procedure described in section 4.4 - Recording the characteristic anode curve

Check that characteristic anode curve is similar to that in Fig. 24. If this is not the case, contact DENEX immediately.

5.0   General specifications

5.1   Gas certificate

euriso-top

PARC DES ALGORITHMES - BÂTIMENT HOMÈRE
ROUTE DE L'ORME
91194 SAINT - AUBIN CEDEX - FRANCE
TELEPHONE DIRECTION   01 69 41 97 98
TELEPHONE COMMERCIAL   01 69 41 95 96
TELECOPIE   01 69 41 93 52
E-MAIL : eurisotop@eurisotop.fr
Website : http://www.eurisotop.fr

ANALYSIS CERTIFICATE

PRODUCT	HELIUM 3
REFERENCE	GHE32L
BATCH	26/010601
LOT	V0261
1 ISOTOPE	3He
2 CHEMICAL FORM	He
3 ISOTOPIC CONTENT	$\geq 99,91\%$

ISOTOPE	3HE	4HE								
CONTENT %	99,91	0,09								

4 CHEMICAL IMPURITIES

ELEMENT	N2	O2 + Ar	CO + CO2	H2	THC					
Vpm	<5	<3	<2	<2	<1					

5 ANALYTICAL METHOD :   Chromatography - ICP MS

Responsable GAZ	DATE	VISA
F. ROBERT	26/01/2006	

5.2 Detector Specifications

			Comments
1	Active area	300 x 300 mm^2	Size of the free space of electrode frames; Neutron sensitive area: ~ 280mm x 280mm
2	Depth of detect. volume	20mm	Limited by drift electrodes
3	Detection gas	^{3}He: 5 bar CF$_4$: 1. bar	Maximal total detection gas pressure: 6 bar
4	Position resolution (FWHM):	2 mm x 3 mm	Horizontally: FWHM 2 mm (due to CF$_4$ pressure) Vertically: FWHM 3 mm (due to CF$_4$ pressure and anode wire distance)
5	Efficiency for thermal neutrons	0.9 Å: > 48 % 2Å: > 76 % 4 Å: > 94 % 8 Å: > 99 % 16 Å: 100 %	i) nominal neutron capture probability inside the detection volume (depth: 20mm) ii) absorption in neutron window not taken into account iii) electronic detection of every captured neutron assumed iv) dead-volume losses between entrance window and first drift electrode can be neglected due to electrode design
6	Window material Window thickness	Al Mg 4,5 Si Alloy 10 mm	Material and thickness is optimized
7	Uncorrected differential non-linearity of position detection	< 3 %	Measurement: Starting from the centre of an uncorrected spectrum and assuming a constant ratio "change in x- or y-position per channel" the relative distortion will not exceed 3%, ie less than 4.5 mm at the border.
8a	Background rate without neutrons	<< 1/s	Depends on the surroundings, the analogue electronics and its adjustment.
8b	γ-efficiency ε_γ	$\varepsilon_\gamma < 10^{-5}$ (E ~ 1 MeV)	Based on efficiencies as measured recently at GKSS for the DENEX-500-CN and DENEX-200CN detectors filled with 1, 1.5 and 3 bar CF$_4$.
9	Electronic components inside the detector	50 Ω Delay lines	
10	Anode wire	Ø ~ 8 μm	Au-coated Tungsten/Rhenium wire
11	Cathode wire	Ø ~ 30 μm	Au-coated Tungsten/Rhenium wire
12	Drift electrodes		Metallic-coatings on isolating layers on window and bottom of the detector
13	Connector for HV supply	50 Ω SHV	
14	Connector for delay lines signal	50 Ω SMA	
15	Valve for pumping and gas filling • Manufacturer • Type	 Swagelok 6L-ELD8-DDXX	
16	Gas quality: ^{3}He ^{4}HE	 99,91 0,09	The detector housing is heated to ~ 60°C and evacuated for more than 100h before the detection gas is introduced.
17	delay lines • number of steps • delay per step • total delay • Bandwidth	 150 ~2.7 ns ~ 400 ns 100 Mz	
18	Anode capacity	~ 470 pF	A$_C$
19	Drift capacity	~ 160 pF	
20	Anode work voltage	+2800 V	Plateau regime
21	Anode work current	~0,008 μA	Plateau regime
22	Anode work resistor	1 MΩ	R$_A$
23	Drift work voltage	-1100 V max	
24	Anode work current	~0,008 μA	Plateau regime
25	Detector dead time	~ 250 ns	
26	Detector restoration time	T = 470 μs	R$_A$ x A$_C$
27	Dead zones	70 cm min. 78 cm max.	
28	Pressure sensor Type	 DRUCK PTX660	
29	Gaskets	Metallic. INDIUM	
30	Dimensions: • height • width • depth • weight	 ~ 447 mm ~ 447 mm ~ 115 mm ~ 50 kg	
31	EU-Declaration of Conformity	**CE**	The directives covered by this declaration: 97/23/EEC Pressure Equipment directive (PED) Section ECC No. L 18158.1 from 09.07.1997 Test pressure 6 bar gauge pressure according to AD200. Bulletins 5D and W7

5.3   Detector Cross-Section
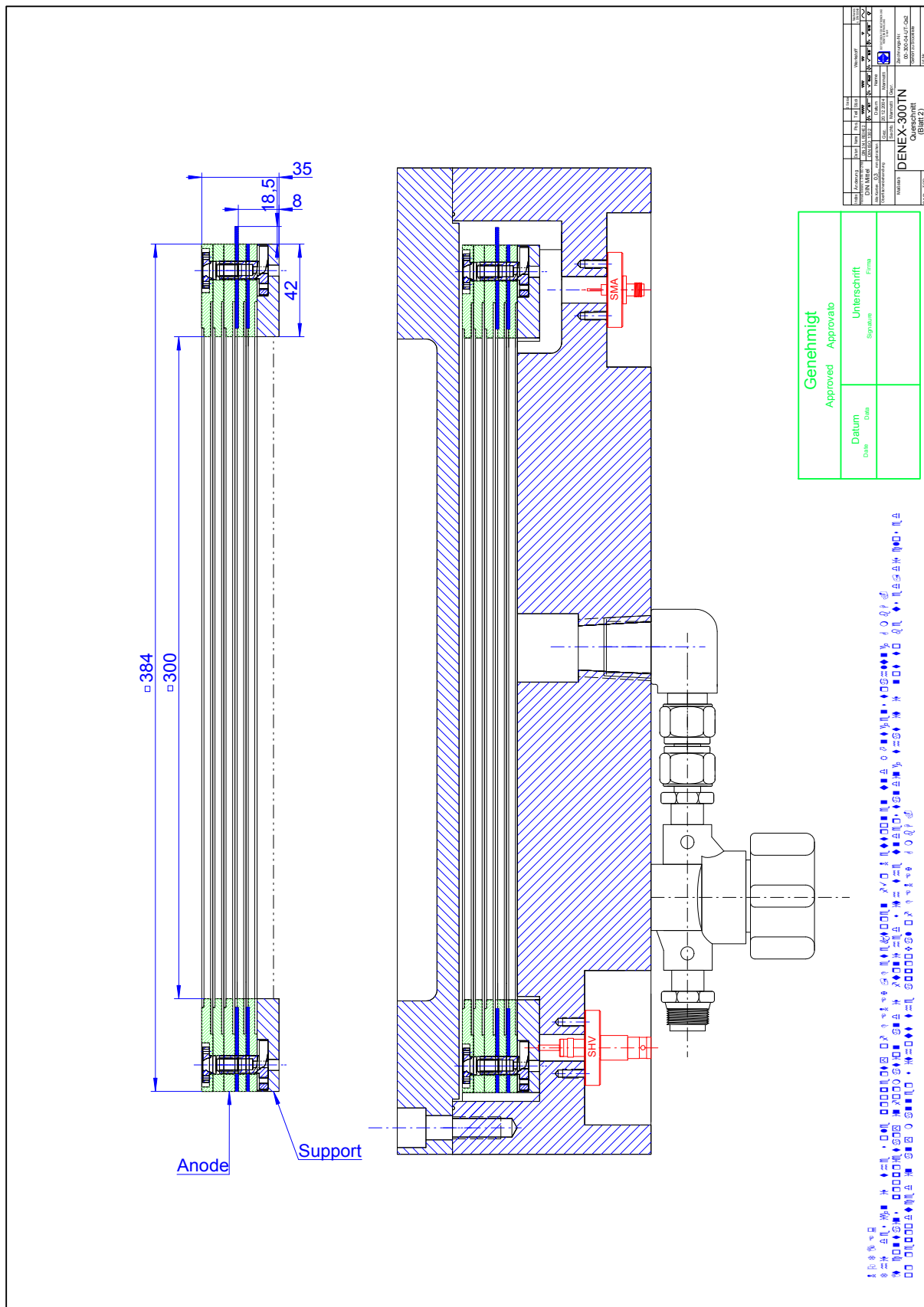
5.4 Detector Front and Rear Views

5.5 Detector Side view

~78

115

447 □

10

M8 Helicoll

M8 Helicoll

M8 Helicoll

M8 Helicoll

M8 Helicoll

M8 Helicoll

M8 Helicoll

M8 Helicoll

DENEX-300TN
Side view